TOTAL DOSE STEADY-STATE IRRADIATION TEST METHOD

ESCC Basic Specification No. 22900

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1 SCOPE

This specification defines the basic requirements applicable to the total dose steady-state irradiation testing of integrated circuits and discrete semiconductors suitable for space applications.

Radiation testing is performed to ensure, within statistical limits and with sufficient margin, that the component lot under test meets the radiation testing requirements of the applicable ESCC Detail Specification and/or the relevant Radiation Test Plan.

Radiation testing shall be considered as destructive.

2 RELATED DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following ESCC specifications form part of, and shall be read in conjunction with this specification:

- ESCC No. 21300, Terms, Definitions, Abbreviations, Symbols and Units
- ESCC No. 21500, Calibration System Requirements
- ESCC No. 22600, Requirements for The Evaluation of Standard Electronic Components for Space Application.

Unless otherwise stated herein, references within the text of this specification to the Detail Specification shall mean the relevant ESCC Detail Specification.

3 TERMS AND DEFINITIONS

The terms, definitions, abbreviations, symbols and units specified in ESCC Basic Specification No. 21300 shall apply. In addition, the following definitions and abbreviations are used.

3.1 DEFINITIONS

Total Dose Radiation Level

The value of total ionising dose specified in the Detail Specification to be used in radiation testing.

The following standardised Total Dose Radiation Levels are defined and are represented by the following specified Total Dose Radiation Level Letters:

Total Dose Radiation Level		Total Dose Radiation Level Letter
RAD(Si)	Gy/(Si)	
3k	30	M
10k	100	D
20k	200	E
30k	300	P
50k	500	F
100k	1000	R
300k	3000	A
500k	5000	G
1000k	10000	H

In-Situ Testing

Electrical measurements performed on components physically located in the irradiation chamber. Electrical bias is continuously applied to the components, except for momentary interruption during measurements.

Remote Testing

Electrical measurements performed on components after removal from the irradiation chamber.

Time-dependent effects

Effects of radiation exposure on electrical parameters, which vary either with the duration of exposure or after completion of the exposure.

Rebound

In MOS structures, a subset of time-dependent effects involving a net degradation of performance due to changes in trapped oxide charge and interface state density over periods of time of the order of several weeks.

Accelerated Ageing

Use of elevated temperature and bias to accelerate Time-dependent effects, especially rebound.

Enhanced Low Dose Rate Sensitivity (ELDRS)

In some cases, bipolar linear components demonstrate increased electrical parameter degradation with decreasing dose rates.

True Dose Rate Effect

A true dose rate effect is observed if, for a given total dose exposure, the degradation after irradiation at low dose rate is different than the degradation at a higher dose rate followed by a room temperature anneal period at least equivalent to the low dose rate exposure time.

3.2 ABBREVIATIONS

ESCIES European Space Components Information Exchange System (See https://escies.org)

ELDRS Enhanced Low Dose Rate Sensitivity

4 GENERAL REQUIREMENTS

4.1 RADIATION TEST PLAN

The selected test samples (see Para. 5.2) shall be subjected to radiation testing as specified within a Radiation Test Plan. The Radiation Test Plan shall essentially contain all information according to the Radiation Test Plan Notes provided in the ESCC Forms section of ESCIES. All electrical parameters testing details, biasing conditions and exposure details shall be clearly specified in the Radiation Test Plan.

When radiation testing is performed in accordance with an ESCC Detail Specification that includes an applicable Total Dose Radiation Level (see Para. 3.1) and radiation testing requirements, unless otherwise specified, the Radiation Test Plan shall reflect the Detail Specification's radiation testing requirements.

4.2 TEST EQUIPMENT GENERAL REQUIREMENTS

The radiation test equipment shall consist of the radiation source, electrical parameter measurement system, test circuit board(s), cabling, interconnect board or switching system, test fixtures and appropriate dosimetry instruments.

Precautions shall be taken to obtain an electrical parameter measurement system which, by use of sufficient insulation, ample shielding, satisfactory grounding etc. shall yield suitably low levels of interference from mains power supplies and other sources of noise and leakage. The magnitude of interference from each of these items shall be sufficiently small so as not to affect any electrical measurement.

4.3 RADIATION SOURCE AND DOSIMETRY

4.3.1 Sources for Ionisation Damage

The radiation source used for the test shall be the field of a Cobalt 60 gamma source or an electron accelerator beam. Alternative sources that can be correlated to these sources may be used but, in the case of dispute, the Cobalt 60 or electron accelerator methods shall govern. The dose at the component under test shall be measured to a resolution of better than ±10% and the non-uniformity of the radiation field in the test area shall not exceed a maximum of ±10%. The field uniformity shall be verified if the geometry of the test setup is changed.

4.3.2 Cobalt 60 Source

The gamma-ray dose rate of a Cobalt 60 source shall be calibrated in accordance with the requirements of ESCC Basic Specification No. 21500 to ±5% or better. Dosimetry shall be traceable to national standards. Corrections for source decay shall be made once per month.

Test specimens shall be surrounded by equilibrium material which will minimise dose enhancement from low-energy scattered radiation by producing charged-particle equilibrium. If it can be demonstrated that low-energy scattered radiation does not cause dosimetry errors due to dose enhancement, then the equilibrium material may be omitted. For equilibrium, the use of a container of at least 1.5mm Pb with an inner lining of at least 0.7mm Al is recommended.

4.3.3 Electron Source

The electron source used for the test shall be a steady-state type. The electron energy shall be sufficient to penetrate the component's body and shall be ≥ 1MeV at the semiconductor die.

The electron beam shall be monitored with a Faraday Cup and a current integrator (which may also be used to terminate the radiation at the specified fluence level). Alternative monitoring methods may be used, but, in the case of dispute, the Faraday Cup and current integrator method shall govern. In the case of ionisation effects, the fluence for a given electron energy shall be accurately converted to RAD(Si) and/or Gy(Si) at chip level, taking into account potential dose enhancement effects due to the component's body, high-Z materials, etc.. The dose profile of the beam shall be uniform within ±10% for a distance of at least 24mm or 5 times the chip diagonal, whichever is the greater.

4.4 RADIATION TEST LEVEL

Unless otherwise specified, the test samples shall be exposed to the single Total Dose Radiation Level (within ±10%) specified in the Detail Specification.

When applicable, either an alternative single radiation test level, or a series of alternate radiation test levels (i.e. multiple exposures) may be required, and if so, the details shall be specified in the Radiation Test Plan.

4.5 RADIATION DOSE RATES

Unless otherwise specified, the radiation Dose Rate shall be as specified in the Detail Specification.

When applicable, an alternative dose rate may be required, and if so, the details shall be specified in the Radiation Test Plan

The dose rate shall be held constant within ±10% during a given radiation exposure. The Dose rate shall be chosen in such a way that the errors in dose coming from timing errors and initial beam adjustment are kept below ±5%.

Two default dose rates are specified:

1. Standard Dose Rate: 0.36 to 180 kRAD(Si)/hour (3.6 to 1800 Gy(Si)/hour)
2. Low Dose Rate: 36 to < 360 RAD(Si)/hour (0.36 to < 3.6 Gy(Si)/hour)

The Low Dose Rate shall be used when strong time-dependent effects and/or true dose rate effects (e.g. ELDRS) are identified or suspected.

4.6 TEMPERATURE REQUIREMENTS

The test samples shall be irradiated in an ambient temperature of +20 ±10°C which shall not vary by more than ±3°C during the radiation exposure. The room temperature anneal of the test samples (see Para. 5.4(g)) shall not differ in temperature by more than ±5°C from the radiation environment but shall not exceed +30°C, in order to minimize annealing. Electrical measurements shall be performed at the temperature specified in the Detail Specification and/or the Radiation Test Plan.

If the test samples are transported to and from a remote electrical measurement site (remote testing), the temperature of the test samples during transport shall not be allowed to increase by more than 10°C with respect to the temperature of the radiation environment.

4.7 ELECTRICAL MEASUREMENT SYSTEMS

All instruments used for the electrical measurements shall have the stability, accuracy and resolution required for accurate measurement of the electrical parameters of the test samples as given in the Detail Specification and/or the Radiation Test Plan. Any parts of the system required to operate within the radiation chamber shall be insensitive to the required accumulated test doses or be shielded until that condition is achieved.

4.8 TEST FIXTURES

The test samples shall be mounted on circuit boards together with any associated circuitry necessary for application of bias during irradiation or for in-situ measurements. Other than the test samples, any components that are placed on the board(s) shall be insensitive to the required accumulated test doses or be shielded so that that condition is achieved.

For these tests, the test sample terminals shall be electrically connected as prescribed in the Detail Specification and/or Radiation Test Plan. The geometry and materials of the completed board(s) shall allow uniform irradiation of the test samples. If the radiation beam is unidirectional then, unless otherwise specified, the beam shall be perpendicular to the diffusion face of the component's semiconductor chip.

Design and construction practices shall be used to prevent damage by oscillation, and to minimise external noise pick-up and leakage currents and to obtain accurate measurements of component parameters. Only sockets which are radiation-resistant and do not exhibit any significant leakages (relative to the test samples) shall be used to connect all components and associated circuitry to the test board(s). Similar precautions shall be taken in respect of cabling and switching systems. All equipment used repeatedly in radiation fields shall be checked periodically for physical and/or electrical degradation.

To assess interference and leakage, a circuit board shall be connected to the entire system with no test components installed and all sources of noise and interference operative, but with no radiation field applied. The current, as measured for the specified bias between any 2 terminals on each empty socket, shall not exceed 10% of the lowest current value given in the Detail Specification and/or the Radiation Test Plan for pre-irradiation values.

4.9 TEST SET-UP AND SITE REQUIREMENTS

The Radiation Test Plan shall state whether electrical parameters shall be measured in the radiation chamber (in-situ testing) or after the test samples have been removed from the chamber (remote testing). In the case of applications for which time-dependant effects are important, the advantages of each method shall be carefully weighed against the disadvantages.

4.9.1 In-Situ Testing

Prior to being irradiated, each test sample shall be checked for operation according to the Detail Specification and/or the Radiation Test Plan. When the entire system is in place for in-situ testing, it shall be checked for proper interconnections, leakage and noise level. The system shall be monitored for oscillations and current drain. The test samples shall remain in place on the test circuit board which itself shall remain in its irradiation location throughout the irradiation and measurement sequence (except for source types which require removal of the board from the irradiation location to end an irradiation).

To ascertain the proper operation and stability of the measurement system, a control component (the unirradiated control, see Para. 5.2) shall be measured with the measurement system before the insertion of test samples and again upon completion of the irradiation and measurement series after removal of the test samples.

4.9.2 Remote Testing

Unless otherwise specified in the Radiation Test Plan, all terminals of each test sample shall be shorted together after removal from the radiation bias fixture. Before and after all electrical measurements on irradiated components, the unirradiated control shall be measured according to the Detail Specification and/or the Radiation Test Plan requirements to confirm proper operation of the measurement system.

4.9.3 Bias Conditions

(This paragraph applies to the voltage applied to high impedance terminals such as gates of MOSFETS and reverse bias to junctions).

While connected to the bias fixture, the biasing condition for the test samples, including the values of voltage and duty cycle, shall be maintained and monitored to remain within ±10% of the conditions specified in the Detail Specification and/or the Radiation Test Plan. If these limits are exceeded, the test shall be void. Unless otherwise specified, the bias applied to the test samples shall be worst case conditions to produce the greatest radiation-induced damage to those components. The specified bias shall be maintained at all times on each test sample except for the periods required for electrical parameter measurements. Unless otherwise specified, the worst-case bias condition shall be determined during the evaluation phase (ref. ESCC No. 22600). During the room temperature anneal (Para. 5.4(g)), test samples shall be mounted on boards providing the same bias condition as used for irradiation.

4.10 TIME INTERVALS FOR MEASUREMENT

Unless otherwise specified, the time intervals given below shall be observed during testing. Justifications for longer intervals shall be reported together with appropriate bias conditions to be used during transport and storage.

(a) The time interval from the completion of an exposure to the start of the measurement of parameters shall be a maximum of 1 hour.

(b) The time interval from the completion of an exposure to the start of the next exposure shall be a maximum of 2 hours (when applicable).

5 PROCEDURE FOR RADIATION TESTING

5.1 RADIATION TEST PLAN

Radiation testing shall be performed in accordance with the Radiation Test Plan (see Para. 4.1)

5.2 SAMPLE SELECTION

Unless otherwise specified, a minimum of 11 test samples shall be selected at random from the wafer lot under test. One sample shall be designated an “unirradiated control”.

The sample size for each unique set of test conditions as defined in the Detail Specification and/or the Radiation Test Plan shall be at least 5. In addition, at least 5 samples shall be irradiated unbiased.

Unless otherwise specified, all test samples shall have met all the requirements of the applicable ESCC Generic and Detail Specifications up to the point of selection for radiation testing.

5.3 SAMPLE SERIALISATION

Immediately after selection, each individual test sample shall be serialised to facilitate pre- and post- irradiation data identification and comparison. The system of marking shall be such as to ensure that the samples are clearly identified by:

(a) a unique, individual serial number.
(b) a Date Code and Wafer Lot Number.

5.4 RADIATION EXPOSURE AND TEST SEQUENCE

Unless otherwise specified, the sequence and details of steps for the radiation exposure and testing performed in accordance with the Radiation Test Plan on the selected test samples and the unirradiated control shall be as follows (see Para. 4 and Figures 1 and 2):

(a) Serialisation of test samples and the unirradiated control (see Para. 5.3).
(b) Initial electrical testing of test samples and the unirradiated control, with special emphasis given to parameters being tested after irradiation. All tested parameters shall be recorded in the Radiation Test Report against serial numbers (see Para. 5.5).
(c) Set-up of radiation source and bias of test samples for irradiation.
(d) Irradiation of test samples to the specified radiation test level (exposure).
(e) Post-radiation electrical tests on the exposed test samples and the unirradiated control. All tested parameters shall be recorded in the Radiation Test Report against serial numbers (see Para. 5.5).
(f) If multiple exposures are required, steps (c), (d) and (e) shall be repeated until the specified maximum exposure/radiation test level has been reached (see Para. 4.4 and Figure 2).
(g) Room temperature anneal, under bias (see Note 1), for 24 hours (unless otherwise specified); followed by post-anneal room temperature electrical testing of the exposed test samples and the unirradiated control, performed no more than two hours after completion of the room temperature anneal (see Paras. 4.6 and 5.5).
(h) Accelerated ageing under bias (see Note 1). The test samples shall be baked at +100 ±5°C, or less if specified, under bias for 168 hours. Alternative conditions can be specified if these conditions have been demonstrated to cause equal or greater rebound effects (e.g. degradation in speed, timing and output drive) (See Note 2).
(i) Final electrical testing on test samples and the unirradiated control.

NOTES:

1. Test samples irradiated unbiased shall remain unbiased during steps (g) and (h).
2. When it has been clearly demonstrated that the component under test does not exhibit irradiation induced time-dependent effects, step (h) may be excluded subject to suitable justification being given in the Radiation Test Plan.

5.5 ELECTRICAL MEASUREMENTS

If any test sample exceeds any specified limit during the initial electrical testing (see Para. 5.4(b)), that test sample shall be replaced and subjected to initial electrical testing.

In the event that, at any measurement point on any of the test samples, the degradation exceeds the permitted limits, other than during initial electrical testing, the radiation test shall be considered as failed. However, testing shall be continued on all test samples until all the required tests of the Radiation Test Plan have been completed.

The parameters to be measured, their degree of permitted degradation and the applied test conditions shall be as follows:

(a) Initial electrical testing (Para. 5.4(b)) shall be performed in accordance with "Room Temperature Electrical Measurements" of the Detail Specification and/or the Radiation Test Plan.

(b) Post-radiation electrical tests (Para. 5.4(e)) shall be performed in accordance with "Electrical Measurements for Total Dose Radiation Testing" of the Detail Specification and/or the Radiation Test Plan.

(c) Post-anneal room temperature electrical testing (Para. 5.4(g)) shall be performed in accordance with "Electrical Measurements for Total Dose Radiation Testing" of the Detail Specification and/or the Radiation Test Plan.

(d) Final electrical testing (Para. 5.4(i)) shall be performed in accordance with "Electrical Measurements for Total Dose Radiation Testing" of the Detail Specification and/or the Radiation Test Plan.

5.6 REPORTING

Electrical test results and other observations from radiation testing shall be collected in a Radiation Test Report. In the event of any significant findings during radiation testing, appropriate recommendations shall be made and included in the Radiation Test Report.

When considered appropriate, recommendations for the modification of future radiation tests (including, as applicable, recommended changes to the Detail Specification) shall be made.

5.7 CONFIGURATION CONTROL

If radiation testing is performed as part of ESCC evaluation, ESCC qualification/qualification maintenance, or procurement of an ESCC qualified component, the component Manufacturer is responsible for keeping the Radiation Test Plan and Radiation Test Report under configuration control. Copies are to be provided to the ESCC Executive in unencrypted electronic format.

In any other case, the Radiation Test Plan and Radiation Test Report are deliverable only to the Customer.

6 DOCUMENTATION

For each radiation test, 2 sets of documents are required to be provided to the ESCC Executive and/or the Customer (see Para. 5.7) as follows:

(a) A Radiation Test Plan (to be provided for approval prior to radiation testing) defining the detailed requirements of the radiation testing to be performed.

(b) A Radiation Test Report giving the actual test conditions and test results.

As a minimum the Radiation Test Report shall include the following:

- Component traceability information:
  - Full Manufacturer's part type number
  - ESCC Component Number (if applicable)
  - Manufacturer's name
  - Test samples serial numbers
  - Date code
  - Wafer lot number
  - Component body type and marking
  - Die photograph
  - Part technology/process details
  - Wafer number(s) (if known)
  - Die fabrication facility (if known)
- Radiation conditions:
  - Test date
  - Radiation facility and radiation source type
  - Radiation test sequence with full details of irradiation and annealing steps including the radiation test level(s) applied
  - Dose rate applied
  - Accuracy of the dose levels
- Bias conditions during irradiation with identification of samples per bias conditions
- Electrical test conditions and applied parameter limits
- Test results (tabulated and in chart form) for each electrical parameter measured, showing the measurement results after (each) irradiation step and anneal of all test samples and the unirradiated control.
- Full details and description of any failures and/or anomalies that occurred during the testing
- Any recommendations applicable to the component lot under test or for the modification of future radiation testing (including, as applicable, any recommended changes to the Detail Specification).

FIGURE 1 - FLOW CHART FOR SINGLE STEP RADIATION TESTING

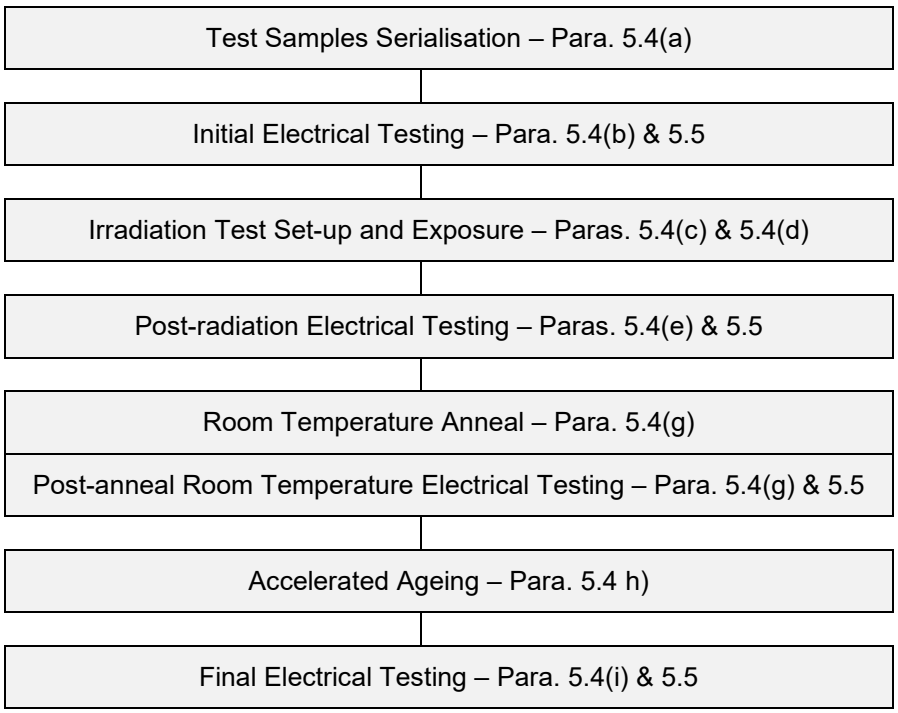


FIGURE 2 – FLOW CHART FOR MULTIPLE-STEP RADIATION TESTING

